Report for 2002NJ3B: Measurement and Prediction of Hydraulic Properties Needed to Model Groundwater Quality in Southern New Jersey

There are no reported publications resulting from this project.

Report Follows:

Progress Report: Measurement and Prediction of Hydraulic Properties Needed to Model Groundwater Quality in Southern New Jersey

Problem and Research Objective

Despite the importance of groundwater quality issues in New Jersey, information on hydraulic properties of soils and sediments is fragmentary and incomplete. Water retention and especially unsaturated hydraulic conductivity are properties difficult to measure and extremely variable through a landscape. Thus, a large number of samples are required to characterize a region. A viable compromise is to obtain reliable estimates from soil properties that are available or easy to obtain. For instance, soil properties typically used to predict hydraulic properties are sand, silt, and clay content, bulk density, and soil organic matter content. In general, statistical models used to predict properties that *we need* from properties that *we have* are known as *pedotransfer functions*.

The main hypothesis of this study is that measurement of hydraulic properties on representative soils and sediments of southern New Jersey will result in a core database from which the most accurate predictive models (pedotransfer functions) for these properties will be selected or developed. More importantly, our underlying hypothesis (supported by the bulk of scientific literature in the subject) is that accurate predictions of hydraulic properties are essential for improving the prediction of the fate and transport of contaminants through the vadose zone. The latter predictions are needed to quantitatively evaluate land management practices prior to their implementation. Consequently, the objectives of this project are:

1. Sample the main soil horizons in southern New Jersey and measure water retention and hydraulic conductivity functions.
2. Use sediment samples collected by the USGS in southern New Jersey to select and measure water retention and hydraulic conductivity functions on representative subsurface layers.
3. Test selected pedotransfer functions of both water retention and hydraulic conductivity functions on soil and sediment data collected from the first two objectives.
4. Modify or develop new pedotransfer functions specific for soils and sediments of southern New Jersey.

Methodology

Two types of samples are being presently analyzed:

1. In summer-fall 1996 unsaturated zone sediment was sampled by USGS (Trenton) personnel during the installation of shallow ground water observation wells at 48 sites. Site locations were selected at random within major land use categories to provide an assessment of ambient shallow ground water quality (Stackelberg et al., 1997). Core samples were collected throughout the unsaturated zone by driving a 61-cm long by 5.1-cm diameter split-spoon sampler with a drill rig hammer. Multiple sediment layers evidenced by visible color and texture changes were noted and the core samples were stored.
2. In spring 2003, three deep profiles were dug and sampled in coordination with NJGS personnel. The profiles were located in three Rutgers off-campus experiment stations located at Cream Ridge (Rutgers Fruit Research and Extension Center), Chatsworth (Philip E. Marucci Center for Blueberry and Cranberry Research and Extension), and Bridgeton (Food Innovation Research & Extension Center). The sites are part of the NJ Mesonet (Fig. 1).

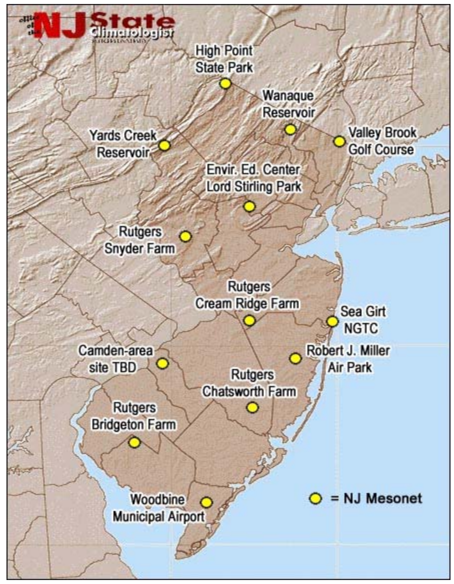

Fig. 1. NJ Mesonet sites.

Information available for each of the 48 wells sampled in 1996 includes site location coordinates, unsaturated zone thickness, moisture content data, bulk density, porosity, and particle size distribution. A more detailed particle size distribution was determined on 109 cores by optical diffraction using a Coulter LS-230 Particle Size Analyzer (Gee, 2002). This method allows for the partitioning of particle sizes ranging from 0.04 to 2000 microns into about 120 bins. Particles larger than 2000 microns (gravel) were sieved out and then integrated into the size-distribution results. Information for the sites sampled in 2003 includes location coordinates and a detailed profile description done according to NRCS procedures.

The constant head method (Klute and Dirksen, 1986) is being used to measure saturated hydraulic conductivity of disturbed samples by measuring steady state water flow through soils and sediments packed in cylinders (5-cm in diameter and 5-cm long). Water retention curves are being measured using pressure plate extractors at 8 pressure potentials covering from -3 kPa to -1500 kPa. For each material, ten replicates of saturated hydraulic conductivity and 4 replicates of each pressure potential are measured.

Seven particle size classes are being measured for each sample material. Hundred grams (100 g) of material are dispersed with 5% sodium hexametophosphate solution, shaken for 5 minutes and sieved through a No.270 sieve to retain particles larger than 0.05 mm (sand). Material that passed the No.270 sieve (silt and clay) is added to a cylinder containing deionized water and stirred at 30°C. A 25 ml sample is collected after 6 hours and 18 minutes from 10 cm below the water surface. The oven-dried weight of the sample is used to calculate clay content. The sand fraction is oven-dried and sieved through a set of sieves to separate gravel and sand types.

An undisturbed block of soil profile was sampled from the C-horizon at the Cream Ridge site (Fig. 2). The block was divided into 6 layers according to color pattern. For each layer, 3 clods were carved and used to determine bulk density according to the method of Brasher et al. (1966). After measuring bulk density, particle size was measured in each clod.

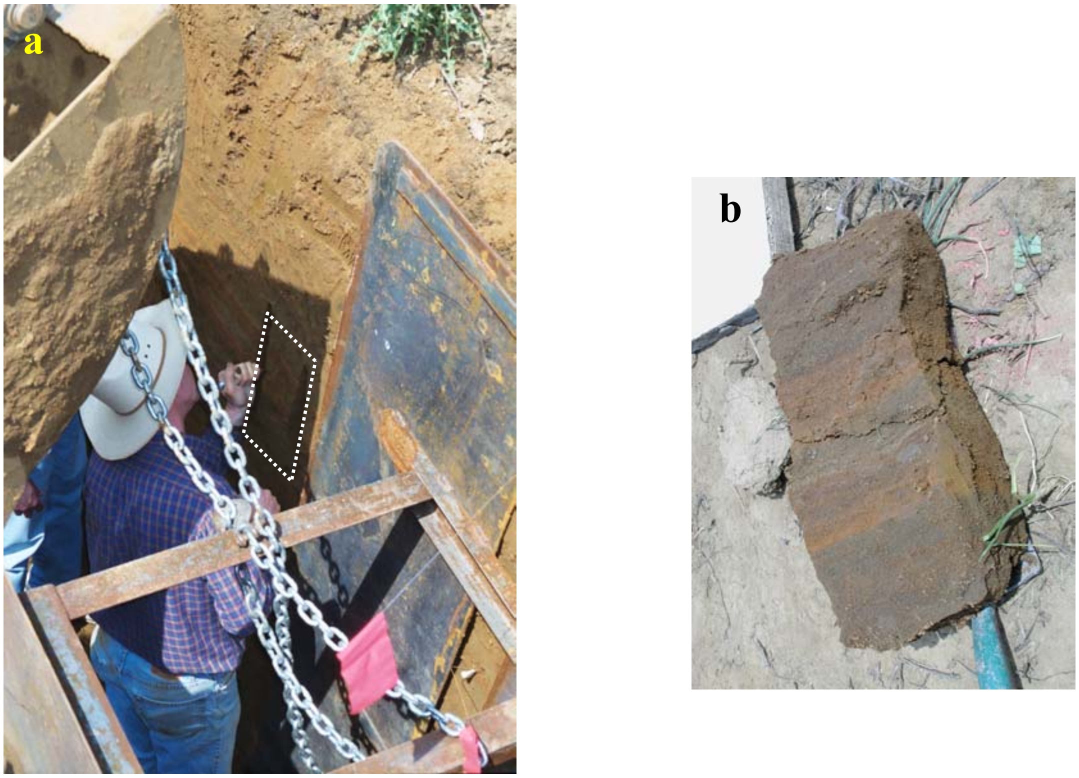

Fig. 2. a) Soil profile at the Cream Ridge site-dashed line shows the position of a sampled block (courtesy of Jeffrey Hoffman-NJGS), b) material sampled from profile showed in a. Differences in color correspond to changes in texture and bulk density (see Fig. 4).

Principal Findings and Significance

We are currently measuring water retention properties and particle size distribution in the material sampled from the NJ Mesonet sites. The vadose zone composition at the sites is distinctively different. At the Cream Ridge and Bridgeton sites we were able to sample 3 m below the surface, whereas groundwater was present at about 1.5 m below the surface at the Chatsworth site (Fig. 3). Layering in the Cream Ridge site (Fig. 2b) resulted in large variations in bulk density.

A detailed study on the relationship between particle size and bulk density revealed that bulk density in the vadose zone of the Cream Ridge site can be predicted from silt content and to a lesser extent by the content of 0.25-0.5-mm diameter sand (Fig. 4). This result is very important to predict changes in bulk density from particle size in these soils and to infer vertical profiles of hydraulic conductivity.

Preliminary results of water retention at the Cream Ridge site show greater retention (on a mass basis) in the A and B horizons (Fig. 5). Identifying the appropriate model is an important step to accurately model vadose zone hydraulic properties. Even though 3 more points of the water retention curves need to be measured, it is clear that the relationship log (water content)-log (pressure potential) is not linear. This fact limits the description of this property to the van Genuchten (1980) model. Analyses of relationships between particle size distribution (measurement in progress) and water retention will facilitate developing prediction tools needed to extrapolate these results to similar settings in the Costal Plain region.

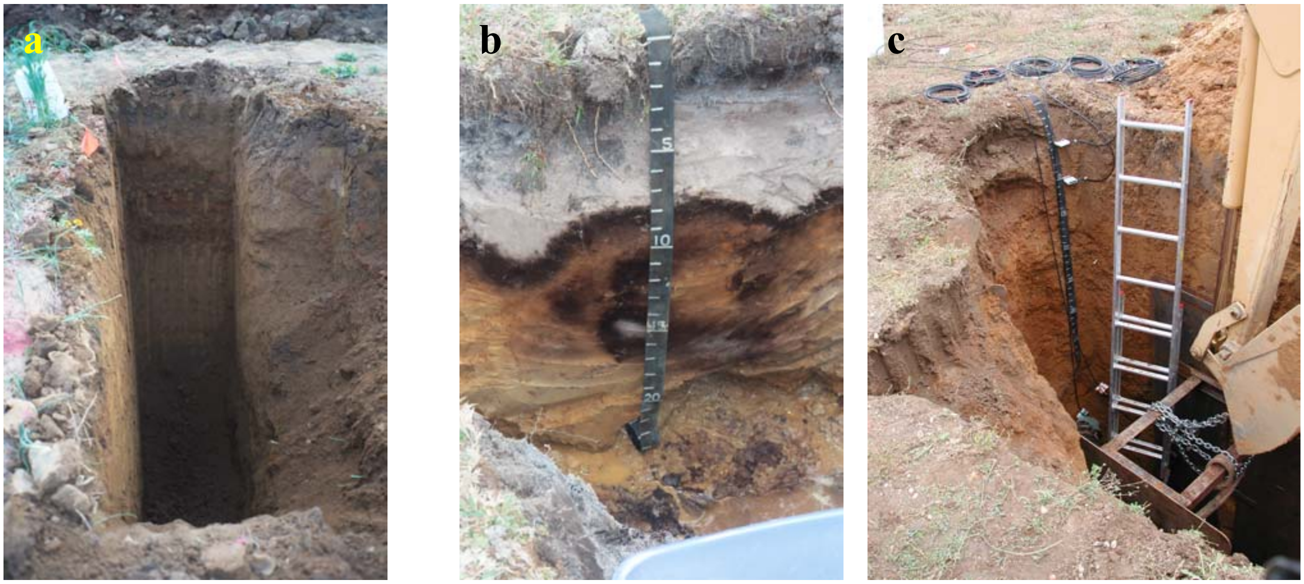

Fig. 3. Vertical profiles at the sampled sites a) Cream Ridge (courtesy of Jeffrey Hoffman-NJGS), b) Chatsworth (courtesy of Jeffrey Hoffman-NJGS), c) Bridgeton.

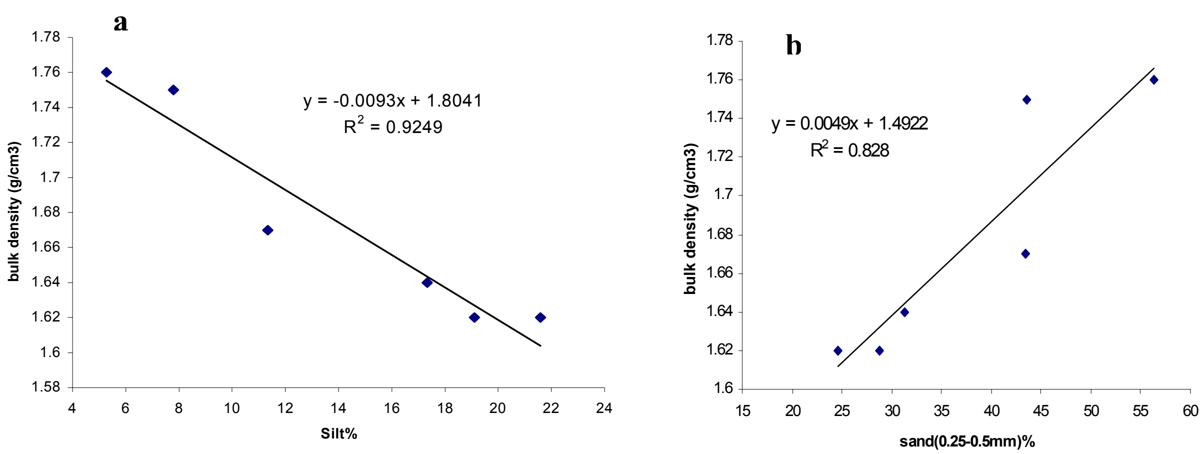

Fig. 4. Bulk density as a function two particle size classes a) silt content, b) sand content for 6 layers sampled from a block of material extracted from the Cream Ridge site (see Fig. 2).

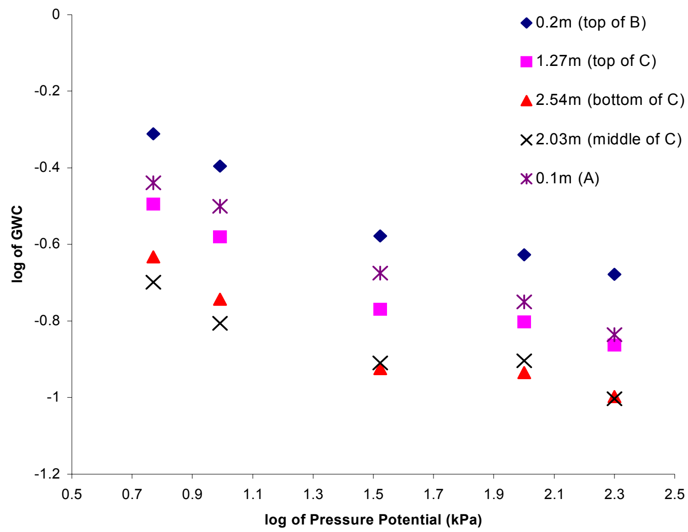

Fig. 5. Water retention curves for vadose zone material at the Cream Ridge site. Each point is an average of 4 replicates. Water content is expressed in gravimetric units.

References

Brasher, B.R., D.P. Franzmeier, V.T. Volassis, and S.E. Davison. 1966. Use of saran resin to coat natural soil clods for bulk density and water retention measurements. Soil Sci. 101: 108.

Gee, G.W., 2002, Particle Size, In J.H. Dane and G.C. Topp, (ed) Methods of soil analysis, Part 1: Physical methods, third edition, American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin [in preparation].

Klute, A., and C. Dirksen. 1986 Hydraulic conductivity and diffusivity: laboratory methods. pp. 687-732. In: Klute, A. (ed.), Methods of Soil Analysis. Part 1-Physical and Mineralogical Methods. SSSA Book Series Number 5.

Stackelberg, P.E., Hopple, J.A., and Kauffman, L.J., 1997. Occurrence of nitrate, pesticides, and volatile organic compounds in the Kirkwood-Cohansey aquifer system, southern New Jersey, U.S. Geological Survey Water-Resources Investigations Report 97-4241, 8 p.

Van Genuchten, M.T., 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 44: 892-898.